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Experimental and Numerical Study of Nanoemulsion Heat Transfer Fluid

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Outline

- Introduction
- Structural Data
- Experimental Results
- Simulation Setup and Results
- Conclusions
- Acknowledgments

Introduction: Nanoemulsion Fluids

- **Definition and formation:** One fluid is dispersed into another immiscible fluid as self-assembled nanosized droplets to create a “nanoemulsion fluid”

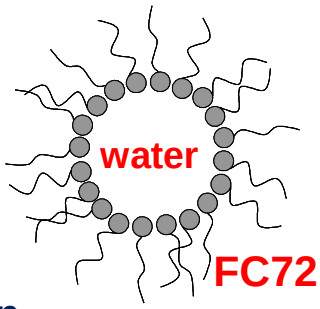


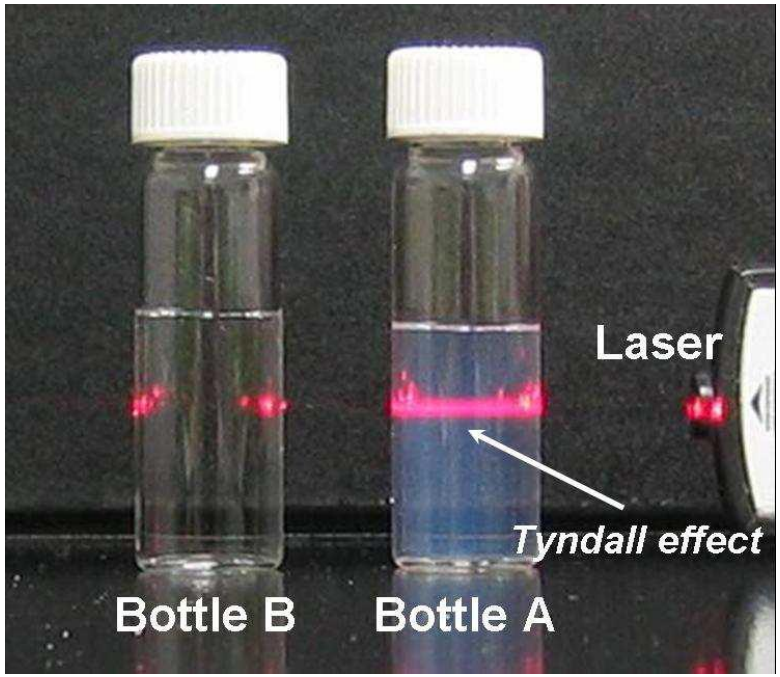
Table 1 Comparison of Nanoemulsion fluids and Emulsion

S.No	***Property***	***Nanoemulsion fluids***	***Emulsion***
1	Appearance	Transparent	Turbid
2	Interfacial tension	Ultra low (usually <<1 mN/m)	low
3	Droplet size	<50 nm	>500nm
4	Stability	Thermodynamically stable, long shelf-life	Thermodynamically unstable
5	Preparation	Self-assembly	Need of external shear
6	Viscosity	Newtonian	Non-Newtonian

Water-in-FC72 Nanoemulsion fluids

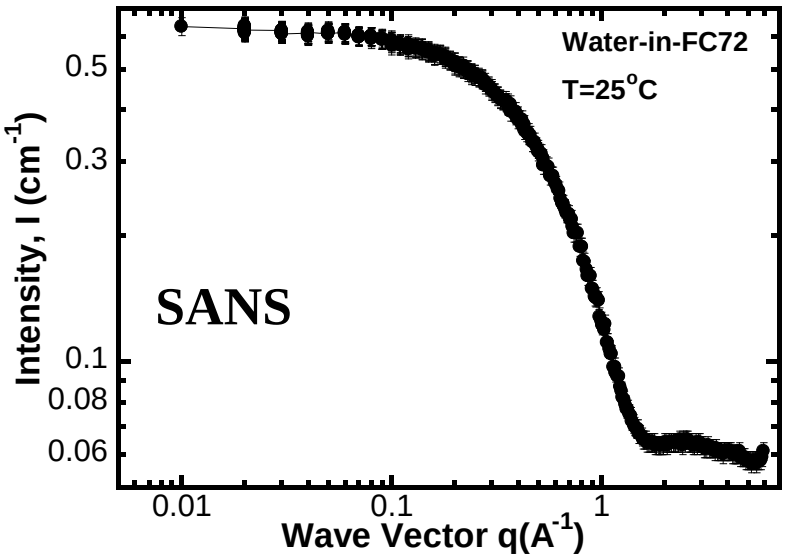
Surfactant: F6H6 & Perfluorooctanoate

Base Fluid: FC72 a clear, colorless, fully-fluorinated liquid, thermally and chemically stable

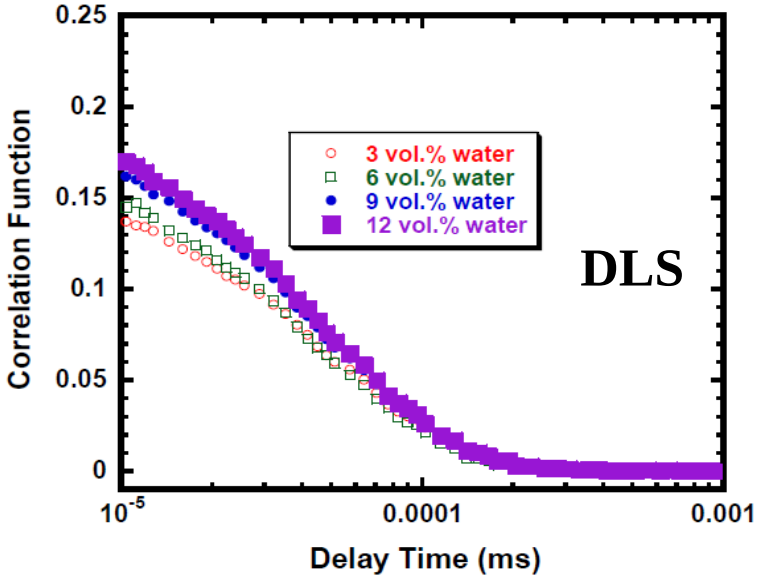


Pictures of Water/FC72 nanoemulsion fluids (Bottle A) and pure FC72 (Bottle B)

Structural Data



Above: SANS Intensity I vs Wave Vector q for Water-in-FC72 nanoemulsion fluids

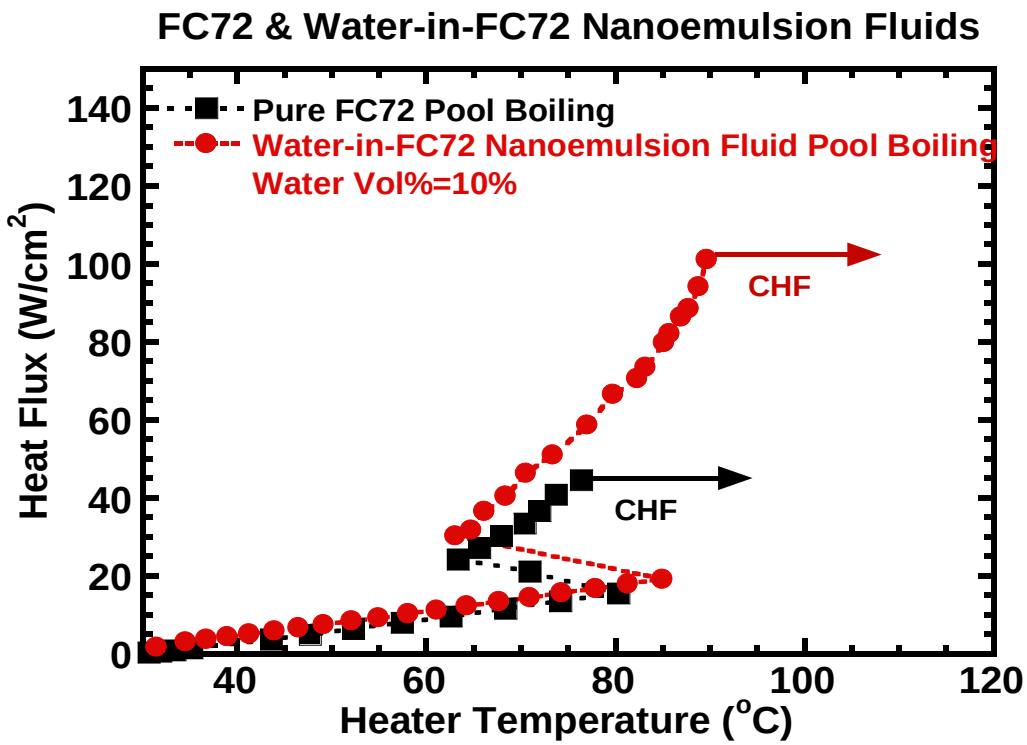


Above: DLS correlation function vs delay time for Water-in-FC72 nanoemulsion fluids

Table 2 Diameter of Water/FC72 nanoemulsion fluids

Volumetric fraction of water(vol.%)	3	6	9	12
Diameter (nm)	10.053	9.7637	8.8991	8.0932

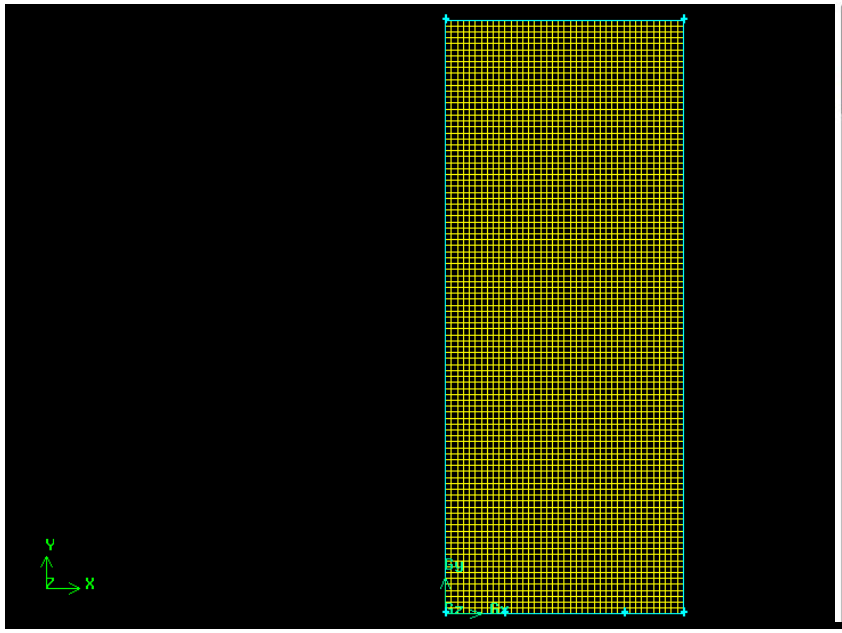
Experimental Results: Boiling Curve

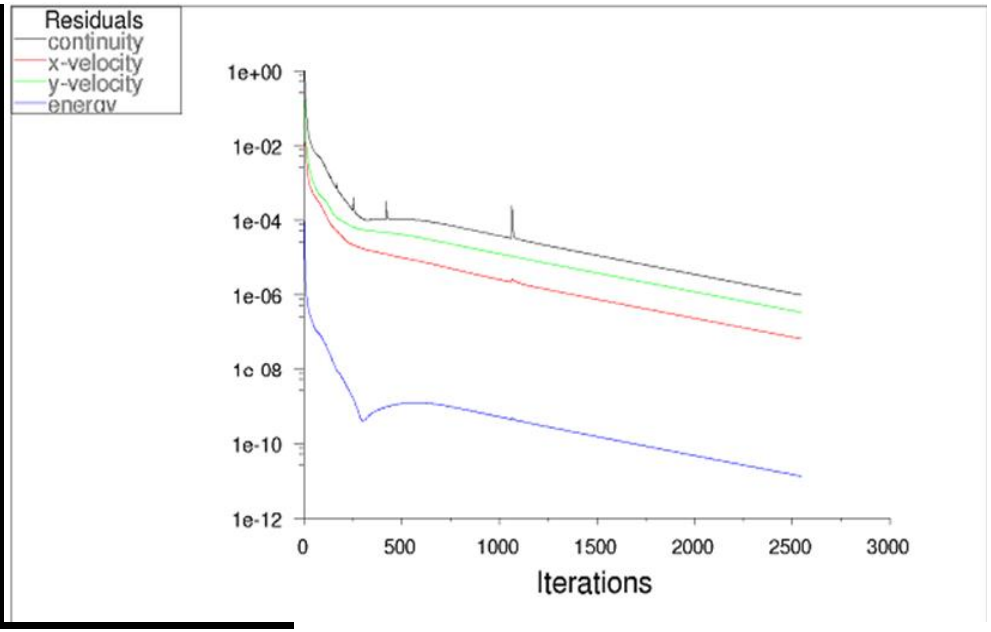


10 Vol% Water-in-FC72 Nanoemulsion fluids

- Enhanced boiling heat transfer capability: wider operation temperature range & higher CHF
- Higher heat transfer coefficient (HTC) after boiling occurs
- No significant change in nucleation temperature
- Boiling hysteresis are observed in both fluids

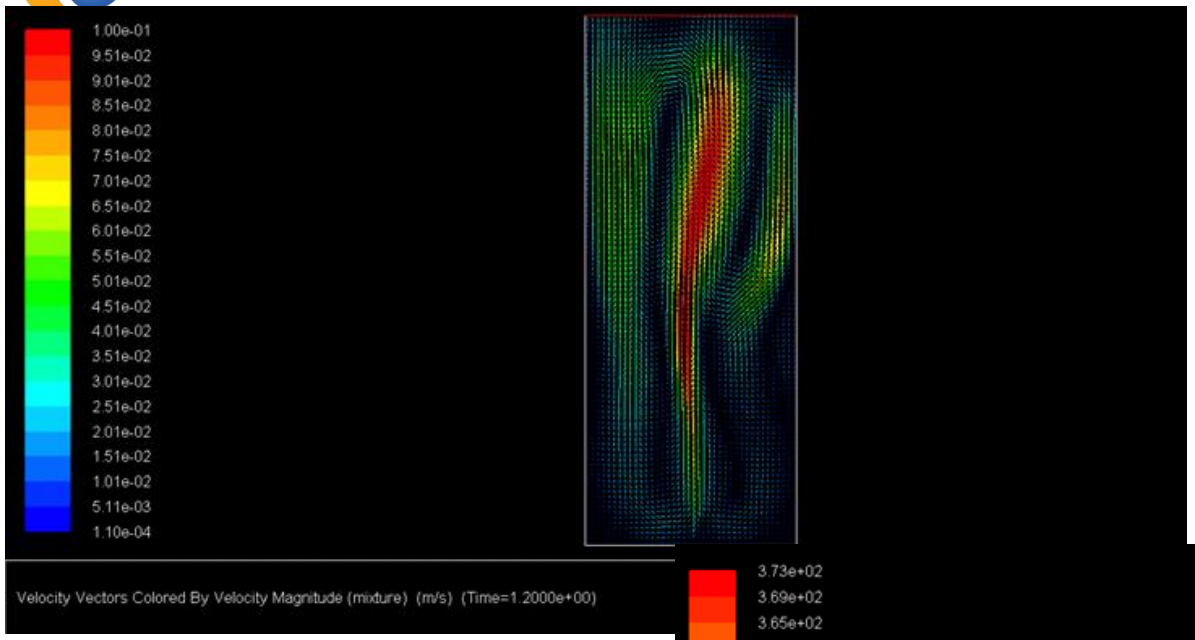
Simulation Setup and Results



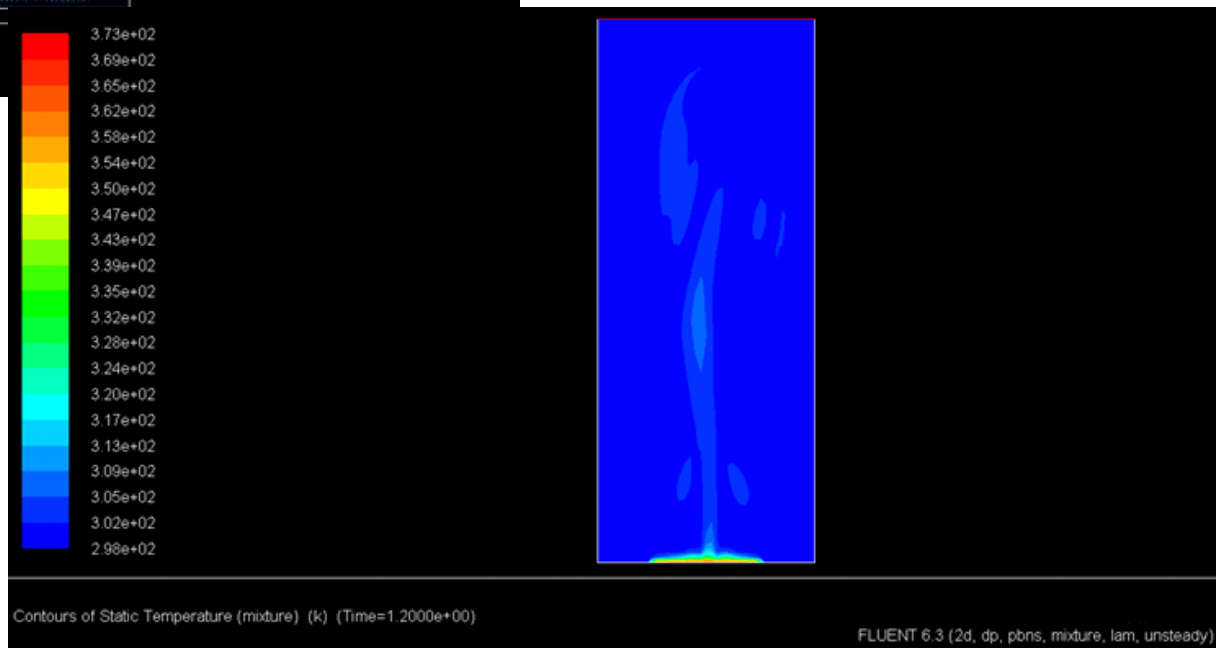


- 2D, double-precision, segregated, laminar
- Plate Pt Heater with controlled temperature Configuration
- Simulate nucleation process inside Water/FC72 Nanoemulsion Fluids

Simulation Results

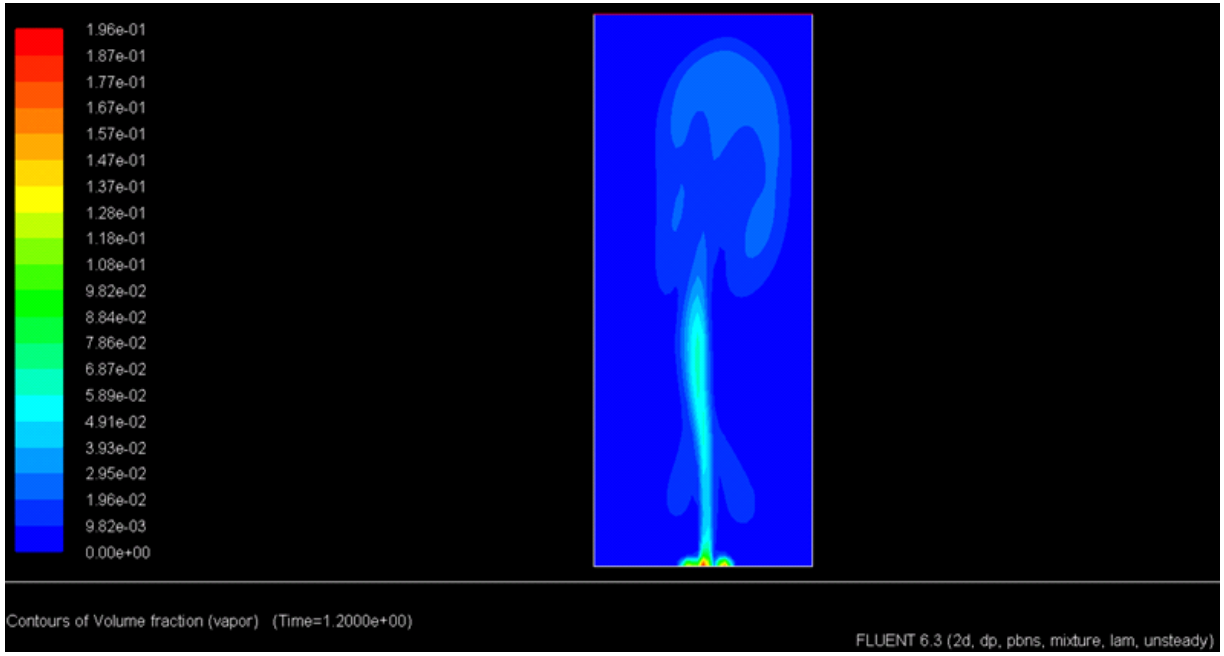


Velocity Vector Magnitude (1.2s)



Static Temperature (1.2s)

Simulation Results



Volume fraction of vapor(1.2s)

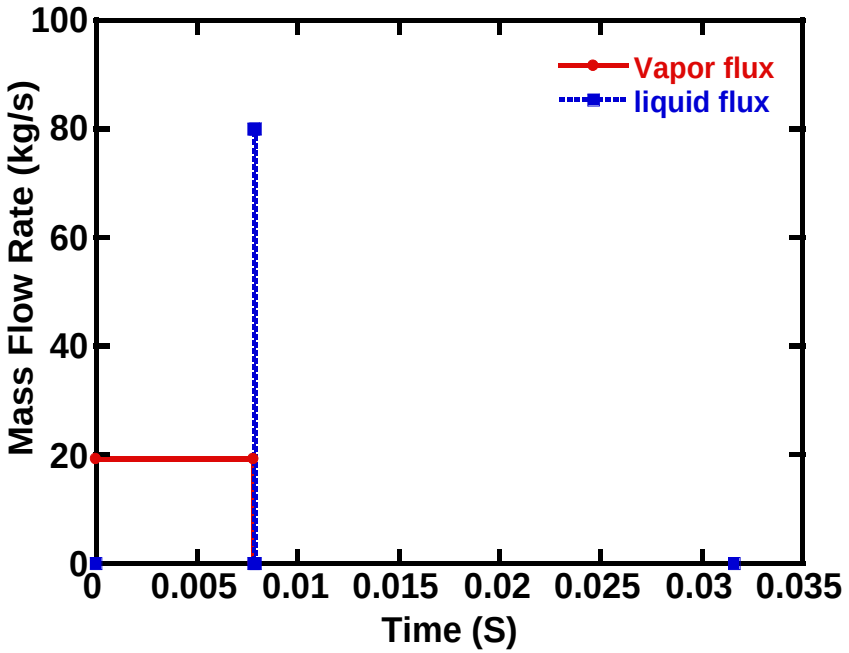
- The mixture model can simulate nucleation process inside Water/FC72 Nanoemulsion Fluids
- Need bubble dynamics simulation

Single Bubble Growth Simulation

High-Speed Camera (Phantom): up to 1500fps at full resolution is used to get the bubble dynamics during nucleation.

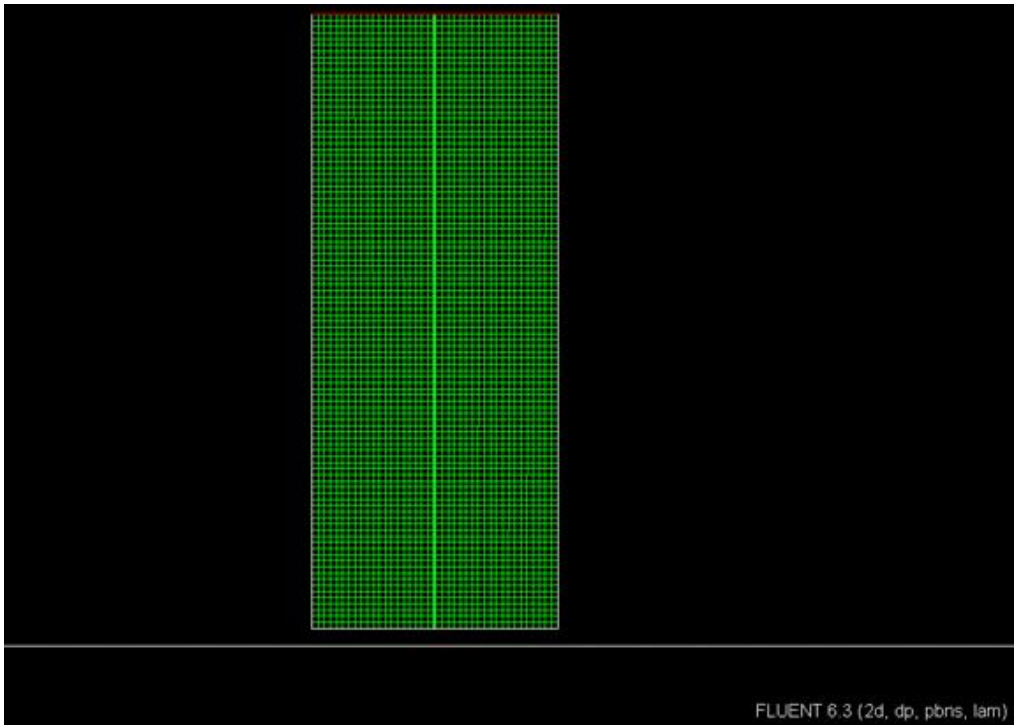
Based upon the observation of the nucleation process under controlled temperature using high-speed camera ,the following bubble dynamics data is used for simulation:

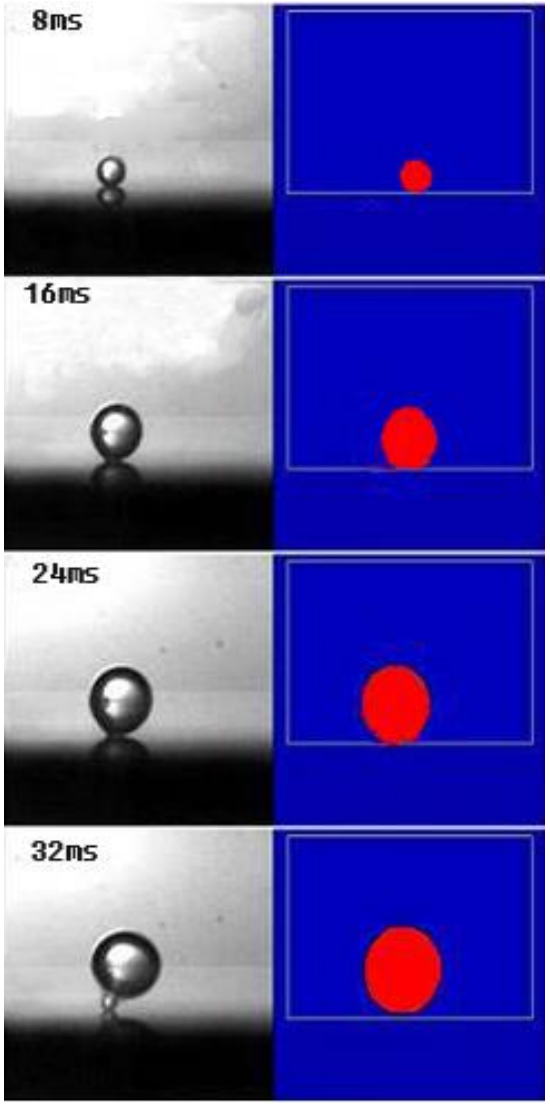
1. Bubble Growth Time: 7.8ms
2. Vapor mass flux: 19.21kg/m^{2}s
3. Bubble Simulation Duration: 31.6ms
4. Wait time : 23.8ms
5. Liquid flux after bubble detachment: 0.1ms



Mass Flux Curve for Simulation

Bubble Growth Simulation Results





- Bubble growth agrees well with camera data

Conclusions

- Water-in-FC72 nanoemulsion fluids has been investigated here and it shows greatly enhanced phase change heat transfer properties
- The pool boiling test has been successfully simulated using ANSYS software which shows good agreement with experimental data
- The transient single bubble dynamics is also simulated here which also shows good agreement with experimental data

Acknowledgement

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Questions?